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Theory and Practice of Non Destructive Testing

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Radiography - 1

Hello everyone and welcome back today I am going to start a new topic which will be on radiographic testing. So like what we do always first we will see the basic principle of this and then we will go onto see the technique how it is done.

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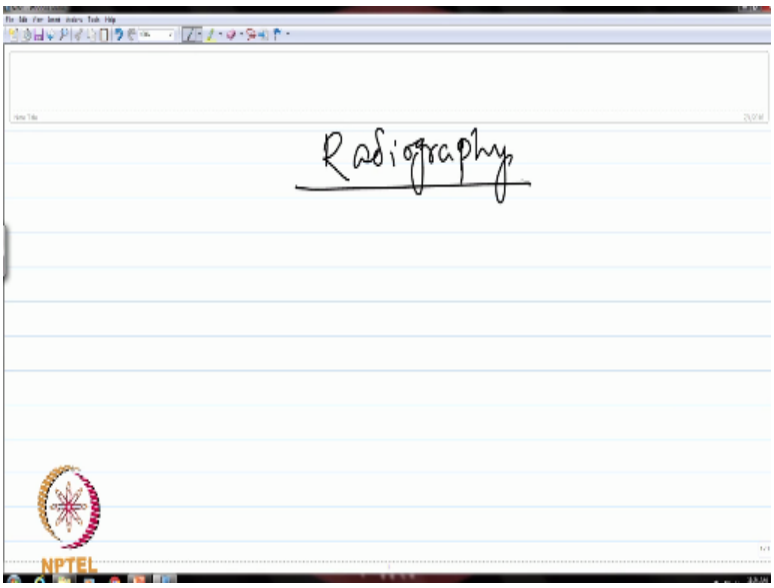

So radiography as you all know is based on or it is done by using x-ray radiation, so before we go on to the basic principle let us first learn a little bit about the properties and nature of x-rays and then we will see how the x-rays in these case are used for doing NDT or radiography.

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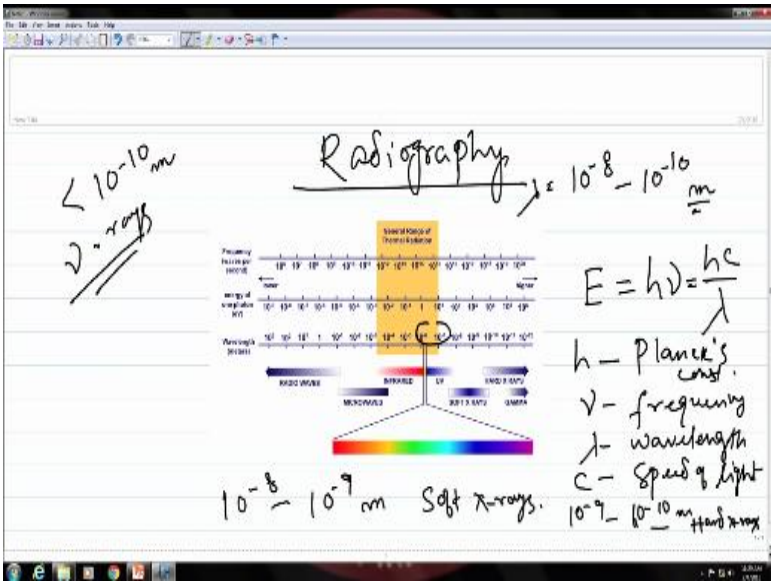

To start with I first want to show you this I am sure you all have seen this at some point of the other this is the electromagnetic spectrum which is also simply known as spectrum where you can see the wavelength and frequency of different types of electromagnetic radiations including a visible light and x-rays okay. So here you can see when you talk about the wavelength it decreases going towards right and increases towards left okay.

So as you decrease the wavelength the energy in the in the electromagnetic radiation will increase because the relationship between the energy E and the wavelength or frequency is given by this wherein h is plance's constant, ν is the frequency, λ is wavelength and C is speed of light okay.

So as you increase the frequency or decrease the wavelength the energy increases okay and you can see the x-rays towards extreme end in the range of 10^{-8} to 10^{-10}m this is the range of

wavelengths for the x-ray radiation which is much lower compared to visible light which is in the range of 10^{-7} okay which will be around this region.

So this tells you that the x-ray radiation is much more powerful compared to the visible light and that is why x-rays can penetrate through materials okay because the energy level in x-ray radiation is much higher compared to what you have in any other electromagnetic radiation, so when you have x-rays in the range of 10^{-8} to 10^{-9}m in this wavelength these are known as soft x-rays and if you increase the energy further that means if you decrease the wavelength to the range of 10^{-9} to 10^{-10}.

Then in this case the energy of the x-rays will be much higher and these are known as hard x-rays okay. And if you further increase the energy and if it is less than 10^{-10}m then this will fall in the γ rays radiation range okay. So this was about the energy which depends on the frequency of the wavelength and due to this very small wavelength x-rays have very high energy and as I said that is why they can penetrate through matter.

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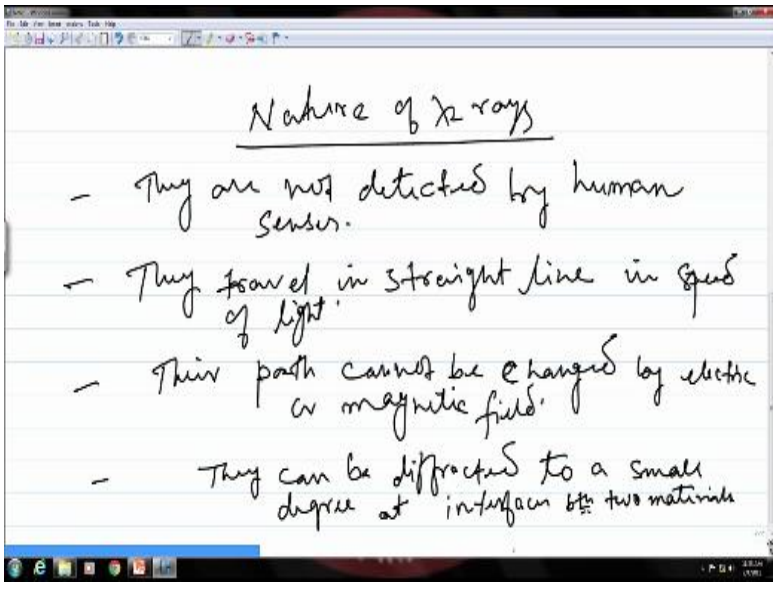

Now if you talk about the nature or a properties of x-rays these are the typical characteristics of x-rays they cannot be detected by human senses you cannot see them, you cannot fill them by any of the organs you cannot detect them. Then they travel in straight line with a speed of light and their paths cannot be changed by electrical or magnetic field, but they can be defected to a small degree at interfaces between two materials.

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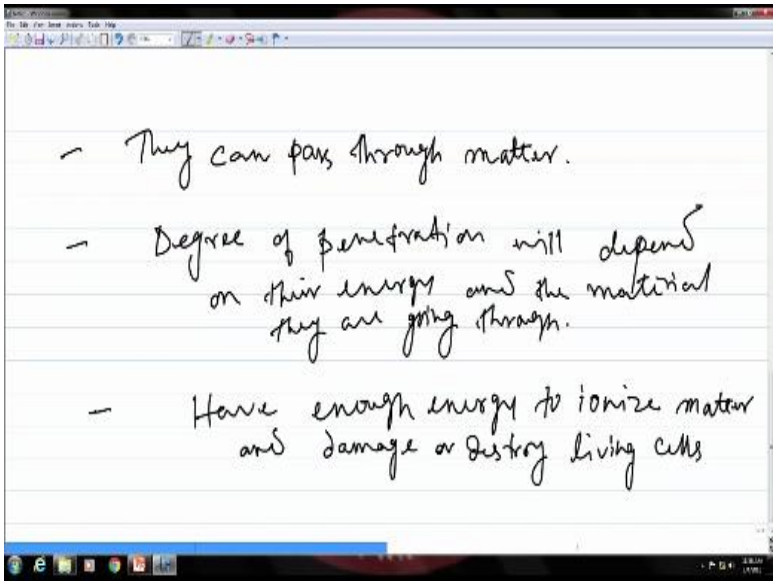

And the other properties are they can pass through matter as I told because of the high energy levels and this degree of penetration we will depend on their energy and the material that they are going through okay. So the every material will interact with the x-rays and the level of penetration will depend on the material properties each we are going to talk about it later and x-rays have enough energy to ionize matter and can damage or destroy living cells.

That is why they are dangerous to human beings you cannot really expose yourself just like that to x-ray radiation you need the shielding and all that and when medical radiation is done for medical radiography in those cases the energy level in the x-rays is much lower, but even then you have seen precautions are given that you are exposed to x-ray radiation okay. So these are the typical properties of x-rays.

And now that we are going to use x-rays to do radiographic testing we should also know a little bit about how these x-rays are generated, because in the radiographic machine also you have extra generator which generates the X rays which are then used to do a radiographic testing okay. So let us see what is the kind of equipment which can be used to generate x-rays.

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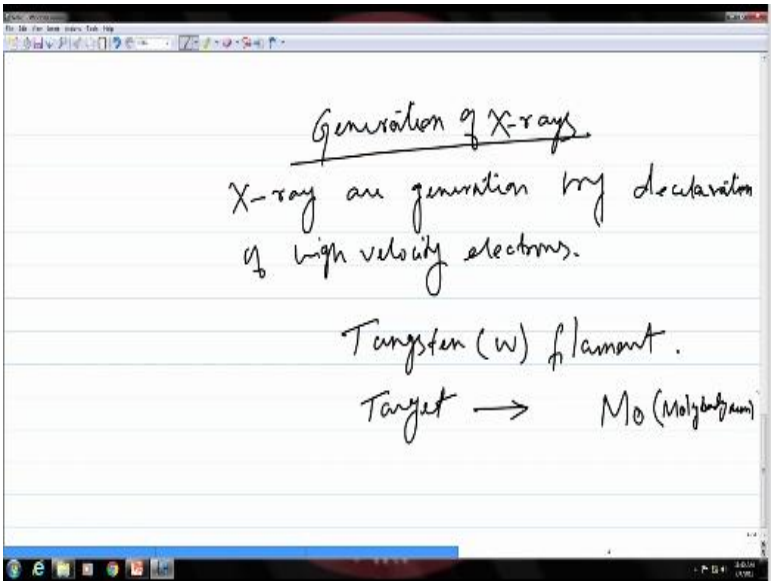

So the basic principle behind generation of x-rays is that x-rays are generated by acceleration and then deceleration of electrons. So first you provide high velocity to electrons and then when you decelerate them this kinetic energy which was provided to the electrons will be converted to x-ray radiation that is the basic principle behind this. So that means you need a source of electrons first and then you need to accelerate them to very high velocities.

And when you stop them on the other end, then this kinetic energy which is provided to the electrons will be converted to x-rays okay. So that means you need two things one is to generate the electrons and the other is to stop the electrons okay. So in order to generate electrons you need a material which can easily emit electrons when you provide a bias okay. So tungsten is one such material which can be used for that purpose.

And tungsten filament is what is used as the electron emitter or the electron source in this case. The symbol for tungsten is w and when you stop it that is on the other side of this instrument which is basically a tube you have another material which stops them. So that is called the target, so here on the target the electrons will come and impact at high velocities and due to that lot of heat will be generated right.

And that is why the target should be made of a material which has very high melting point okay. So that means in this case if you want to use a metal you have to use those metals which have very high melting point and this kind of metals are known as refractory metals because of their high melting points.

And molybdenum is one of them which has very high melting point, so this molybdenum is used as a target on the other side of the tube on which these electrons will impinge at high velocities and their kinetic energy will now be converted into x rays. So in order to provide the kinetic energy to the electrons you need to maintain a very high voltage between this tungsten filament and the target.

So the tungsten filament is the cathode and the target which is the molybdenum in this case is the anode okay. So you need to first generate these electrons from the tungsten filament by providing a bias state and once the electrons are emitted you need to accelerate them towards the anode by maintaining a very high voltage difference between the anode and the cathode okay.

And for the electrons to move from the cathode to the anode you need to create a vacuum between the anode and the cathode okay.

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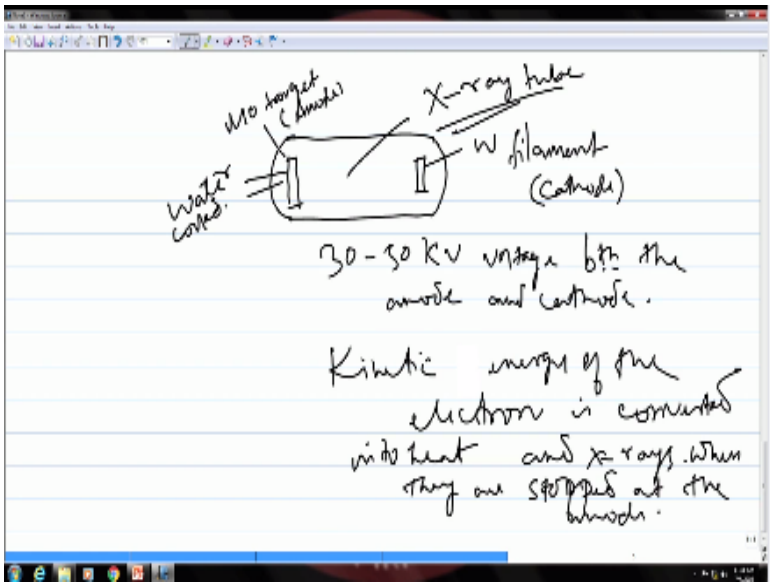

So that means this whole thing has to be done inside a tube and this tube has to be maintained under vacuum okay. So in one side you have the tungsten filament and on the other side you have the target and you keep them inside a tube which is evacuated and kept under vacuum, okay. Now if you maintain a voltage difference to the tune of 30 to 50 kilo volt between the anode and the cathode then these electrons will be accelerated at high velocities towards the anode, okay.

And when they are start up the note that they will be decelerated so there now they are stopped at the anode so this kinetic energy which was there in the electrons will now be converted into some other form of energy most of it will be converted into heat energy and that is why this anode in spite of it being a high melting material it has to be water cooled, because as I said most of the energy in the electrons will be converted into heat and a small fraction of it will be converted into x-rays, okay, right.

So this is how x-rays are generated so this is basically an x-ray tube it is maintained in vacuum and the main components of this tube are these two electrodes the tungsten filament cathode and the molecule anode and then you have to maintain these high bias between the anode and

cathode and then you can change it these x-rays by this energy conversion. So now that we have understood a little bit about x-rays and their properties, so now it is time to our talk about how these x-rays are used to do radiographic testing, okay.

So in order to explain the basic principle behind a geographic testing I would like to first show you this picture, okay.

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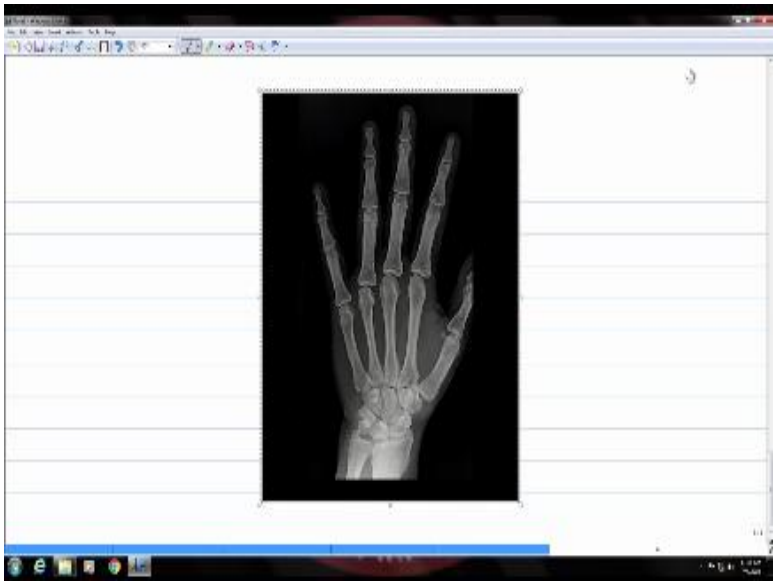

So I like to use this picture to explain the basic principle behind radiographic testing I believe you all have seen this picture at some point in time in your life if not for your own body parts maybe for somebody else but you all have seen this, right. So this is a medical radiograph of our hand and you can see the bones clearly, okay so this is how when you expose our hand to x-ray radiations this is how the image would look like, okay.

The question that I want to ask you here is that the bones that you see they always appear white compared to the rest of the portion of the body okay, have you ever wondered as to why these bones always appear white on a radiograph. The basic principle behind this technique lies in the answer to this particular question okay, as to why the bones always appear white on a radio,

okay. So let me explain that and that will give you the basic principle behind this particular technique.

This goes back to a property of any substance called absorption okay, so whenever x-rays pass through a matter there will be some kind of interaction between the x-rays and the matter and as a result of that some amount of extra energy will be absorbed by that material okay, and this absorption ability varies from material to material okay, and it will depend on some of the material properties and density being the one of the most important properties on which these absorption will depend on.

Now if you look at our body parts bones are the most dense in human body okay, so when the x-rays pass through the bones or when the excess pass through human body bones are the areas where the absorption of the x rays will be much higher compared to any other portion of our body, okay. So what happens when you do radiography you have a x-ray source okay, then you put the body parts or the sample that you want to radiograph and then after that in contact with the sample a radiographic film is kept on which the image is captured, okay. Now this radiographic film is made of a material which darkens on exposure to any electromagnetic radiation including visible light, okay.

So this is nothing but the photographic film or the negatives that you would have seen which are used before to take photographs before the you know before the digital radiography came into picture people used to use this photographic film that we have seen as negatives okay, so this is a very similar thing which is used in case of x-ray radiography also you expose the sample to x-rays and capture the image on the photographic film.

Now as I said the property of the photographic film is to darken when it is exposed to visible light or acceleration, okay.

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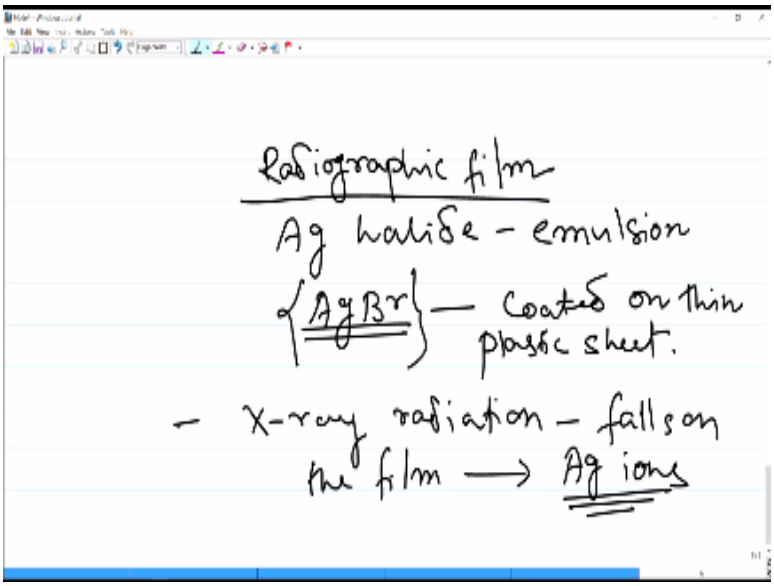

So this x-ray film or the radiographic film that you have this is primarily made of a silver halide emulsion like silver bromide can be used for that purpose, so this emulsion is coated on a thin plastic seat and that is what you see this film as a thin plastic sheet which most of the time appears dark to us because by the time we see it, it is already darkened and the reason why darkens is this silver bromide particles that you have, okay.

So this silver halide or this silver bromide is a material which can easily interact with x-rays and when they interact with x-rays some of the x-ray energy will be absorbed by this material and due to that the bond between silver and bromine will be broken and silver ions will be liberated, okay. So that is what happens when x-ray intensity falls on this film and it liberates the silver ions okay, so this liberated the silver ions are the main responsible factor for the contrast or the darkening that you see on the x-ray film okay.

And this extent of darkening will depend on how much radiation or how much energy is falling on the film, okay. If the energy falling on the film is high then the extent of darkening will be high and vice versa okay, so that means this will depend on how much energy is being absorbed by the sample on a particular part okay, so in this case in this particular radiograph.

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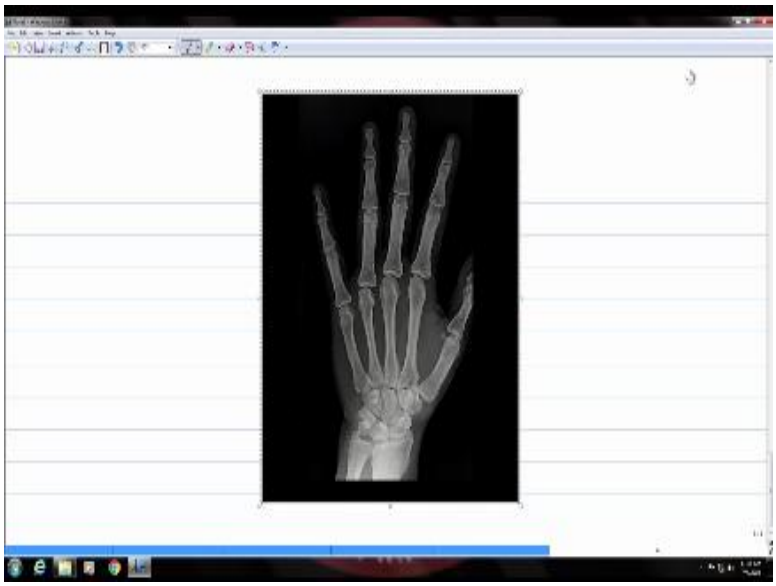

Since the bones are the most dense parts they will absorb more energy compared to the flesh and the tissues around it and that is why the energy coming out from the bones will be much lower compared to energy coming out from other portions of the hand or any other body part and that is why these bones will appear white because the energy coming out from the bones is lower and when it falls on the radiographic film the extent of darkening as a result will be lower compared to any other portion of our body part, okay.

And that is why owing to their high density these bones will appear white on a radiographic image okay, so that is all fine but how do you define it I mean do you have any expression or something that can describe this particular phenomena and yes, we do have an expression through which we can describe this mathematically and that will give us little more understanding as to why this happens and that will help us in turn in understanding the basic principle behind this particular technique, okay.

So let us talk about that particular expression of the equation which is the basis for radiographic testing, okay.

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And you can get an expression like this which in fact can be derived based upon the absorption of x-rays when it travels through a particular material of thickness X that is what you see over here so it will depend on the thickness of the material that is one factor which will control the intensity I which comes out from the material after traveling through this particular distance X and I_0 in this case is the initial intensity.

So the initial intensity falls on the material and then it goes through the thickness of the material and this is the decrease that you see I/I_0 and this decrease is exponential with respect to the distance that the x rays travel and one more parameter that you could see here which is μ so this is a material property which indicates that the extent of absorption will depend on the material through which the x-rays are traveling and this particular parameter is known as the linear absorption coefficient which is different for different materials, okay.

So this we are going to take up in more detail in the next class we will take it up in the next class and we will discuss about it and then see how that can be used in order to form the basis of radiographic testing so for today this is all I have I am going to stop here today and I will see you next time, thank you for your attention.

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